

SECTION X.

REPORT OF THE PANEL ON  
INTERNATIONAL PROGRAMS

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## SECTION X.

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## SUMMARY

Since the beginning of the space age there has been a need for international cooperation. The organizational scheme of these cooperative activities has varied from case to case. Some activities have been placed under the aegis of international scientific bodies, others have been based on ad hoc arrangements. For most of the important scientific results obtained in the field of Earth Sciences based on space techniques, the contribution of international cooperation has been quite substantial. International cooperation in Earth Sciences not only helps in solving problems which are of a global and multi-disciplinary character, but also a better understanding of both our physical and social world. The NASA SES Program must be seen as part of a worldwide endeavor, recognizing that a comprehensive study of the Solid Earth can only be meaningful if all the national and international entities are prepared to contribute to the achievement of agreed goals.

The success of any cooperative effort depends on the observance (or neglect) of a number of ground rules or critical factors. International cooperation is no exception and is subject to the same general conditions, complicated by such things as the prevalence of other languages, the observance of different cultural and educational backgrounds, and operation under varying political structures. As a result, particular elements or ground rules may take on more significance in one relationship than another. Even so, certain basic critical element can be identified which will smooth the road to success in any cooperative venture.

The strengths of international cooperation lie in the avoidance of duplication, the extended base of scientific competence, and the larger reservoir of technical competence. These provide an attractive basis for political agreement and program approval. The weakness on the other hand are the disadvantages brought about by the need to hold more extensive and extended negotiations which can result in the introduction of added restrictions and, in any case, bring about a certain dependence on foreign partners.

Scientific research in the area of Solid Earth will be dictated primarily by the large international programs until far into the 21st century:

- \* the International Decade for Natural Disaster Reduction (IDNDR)
- \* the International Geosphere-Biosphere Program (IGBP)
- \* the International Geological Correlation Program (IGCP)
- \* the International Lithosphere Program (ICL) which includes projects aimed at making significant contributions to the IDNDR and IGBP, namely:
  - Instability of Megacities
  - Risk Assessment of Volcanic Hazards
  - Global Geoscience Transect Through Hazardous Regions
  - Real Time Tectonics
  - Terrestrial Observatories

Additional impetus is expected to come from environmental-related programs such as the:

- World Climate Research Program (WCRP)
- Global Change Program
- Tropical Oceans and Global Atmosphere Program (TOGA)
- Tropical oceans Circulation Experiment WOCE)

Suggested areas of cooperation include:

1. Cooperation in the installation and operation of ground tracking facilities for the different observing techniques. (SLR, VLBI, GPS, DORIS, PRARE);
2. Collaboration in spaceborne instrumentation and missions. (ARISTOTELES, SGGM, TOPO, OVO);
3. Access to observational data and data handling.

The International Panel (consisting of 13 representatives of international countries and agencies):

- \* Expresses satisfaction that the NASA Solid Earth Science Planning Conference recognizes the importance of international cooperation and international programs.
- \* Believes that Solid Earth research needs will greatly benefit by the organization of appropriate international programs, with NASA participation, and well-defined objectives, procedures, and responsibility between partners.
- \* Suggests that all efforts should be made to relate and coordinate the activities of the different SES projects (including NASA's) with the relevant major international programs through the established international bodies such as IDNDR, IGBP, ICL, and others.

The Panel recommends that NASA participates and takes an active role in:

1. the continuous monitoring of existing regional networks such as the WEGENER/Medlas networks;
2. the realization of high resolution geopotential and topographic missions;
3. the establishment of interconnection of the reference frames as defined by different space techniques;
4. the development and implementation of automation for all ground-to-space observing systems;
5. calibration and validation experiments for measuring techniques and data, including remote sensing;

6. the establishment of international spaced-based net-works for real-time transmission of high density science data in standardize formats;
7. tracking and support for non-NASA missions; and
8. the extension of state-of-the-art observing and analysis techniques to the developing countries.

The Panel urges NASA to participate in the organization and implementation of courses, seminars, and training programs especially for the developing countries. Finally, the Panel stresses the importance of the use of proper monumentation and accompanying documentation for the studies of the Earth's geometry, kinematics, and dynamics.

## 1. Introduction

Since the beginning of the space age there has been a need for international cooperation. The fact that satellites were covering most of the Earth's surface required that satellite tracking stations be distributed around the world in order to calculate precise orbits.

The first satellite geodesy results were obtained in the late 1950's for the determination of the flattening of the Earth and the discovery of the third order harmonic term in the Earth's gravity field. These results were derived from observations provided by tracking stations established in different countries. The same was also true for the determination of station coordinates that became feasible in the early 1960's, and enabled geodesists for the first time to tie together the different geodetic datums.

When it was realized that the study of the Earth using space techniques in terms of its size, shape and gravity field, required global tracking coverage, different international observation campaigns were organized under bi- or -multinational arrangements. The Geodetic Satellite Program initiated by NASA and the InterCosmos Project established by the USSR Academy of Sciences were typical multilateral activities in the 1960's. The first real internationally organized observation and analysis program in this field was ISAGEX (1971), which was initiated by CNES and operated under the auspices of IUGG-IAG and COSPAR. It should be pointed out that NASA has been quite active in participating and initiating these and other such international programs.

The organizational scheme of these cooperative activities has varied from case to case. Some activities have been placed under the aegis of international scientific bodies, others have been based on ad hoc arrangements.

International cooperation in Earth Sciences using space techniques has not only been limited to the organization of observation campaigns, and the exchange of data. It has extended also to theoretical work and development of software, as well as to the analysis, the modelling, and the interpretation of the results. Joint development programs such as LAGEOS 2 and TOPEX/Poseidon are also examples of such international cooperation.

It should be recognized that for most of the important scientific results obtained in the field of Earth Sciences based on space techniques, the contribution of international cooperation has been quite substantial. International cooperation in Earth Sciences not only helps in solving problems which are of a global and multidisciplinary character, but also a better understanding between nations, peoples and disciplines, contributing to a better understanding of both our physical and social world.

## **2. The Rationale for International Cooperation**

It is important to realize that the NASA Solid Earth Science Program must be seen as part of a worldwide endeavor, recognizing that a comprehensive study of the Solid Earth can only be meaningful if all the national and international entities are prepared to contribute to the achievement of agreed goals.

### **2.1 Scientific Cooperation**

In the fields of Solid Earth Sciences, investigations cover new topics of such complexity that in most instances it can no longer be considered the prerogative of an individual agency, nation or group of nations to assume sole responsibility for their organisation, operation and analysis. The major issues in Solid Earth research are global in nature and have to be addressed appropriately. Thus, encouraging international cooperation among scientists and extending the base of scientific competence should be one of the axioms of NASA's policy for international cooperation.

#### **2.1.1 Assessment of the Strengths and Weaknesses of International Cooperation**

The success of any cooperative effort depends on the observance (or neglect) of a number of ground rules or critical factors. International cooperation is no exception and is subject to the same general conditions, complicated by such things as the prevalence of other languages, the observance of different cultural and educational backgrounds and operation under varying political structures. As a result, particular elements or ground rules may take on more significance in one relationship than another. Even so, certain basic critical elements can be identified which will smooth the road to success in any cooperative venture.

From the outset, it can be assumed that each of the participating groups or agencies is seeking, through the cooperation, to upgrade its own competence, by accessing those areas of superior ability or accessibility that are available to the other partners. This is not only a legitimate stance, but it can be used to the general benefit of the community of participants, if negotiations are carried out in the appropriate manner. One-way exploitation of potential partners leads ultimately to unnecessary antagonisms and tensions between the participants.



## **2.1.2 Critical Elements**

Past experience has highlighted a number of critical elements which have influenced the success of different activities. These elements are usually identified by association with the appearance of some problem or other which should preferably not be repeated. A key element lies in the selection of the right partners. Where these are in any case dictated by circumstances, this becomes a search for the appropriate contacts.

It can always be assumed that a participant's involvement occurs against a justified background of national, agency or institutional interest. The motivation for participation may, for example, be dictated by the economic interests or by the technological advancement of the society in which the participating group exists, by scientific interest, by the efforts to improve access to advanced technologies, education and management, by the need to expand or upgrade industrial effort, by exposure to potential natural hazard, or by a combination of these factors. Furthermore, there are differences in budgetary systems which need to be identified and compensated for, where necessary.

Accepting this, it is desirable to have a clearly identified concept of the motivation of the various participating groups, and it is essential that the scientific objectives be clarified early in the cooperation. Procedures and areas of responsibility also need to be defined, documented and agreed by all partners in the early phases of the activity. Position papers which are prepared and published by one agency or institution without consultation with the other partners are susceptible to misinterpretation and create unnecessary sensitivities.

Another area deserving particular attention addresses data access and sharing conditions, which should be agreed from the beginning and the conclusions made known to the community of active participants.

## **2.1.3. The Strengths and Weaknesses**

The foregoing comments make it apparent that international cooperation can be characterized by a number of strengths and weaknesses. The strengths lie in the avoidance of duplication, the extended base of scientific competence, and the larger reservoir of technical competence. These provide an attractive basis for political agreement and program approval.

The weaknesses on the other hand are the disadvantages brought about by the need to hold more extensive/extended negotiations which can result in the introduction of added restrictions and, in any case, bring about a certain dependence on foreign partners.

It seems apparent, however, that the advantages outweigh the disadvantages.

## **2.2. Programmatic Cooperation**

The study of the Solid Earth system, in particular its structure and its potential fields, is dynamic and requires on the one hand a complete coverage of the planet on a continuous basis and on the other hand an appropriate time repetitivity of observations at different spatial scales (local, regional, global), depending upon the various scientific disciplines or application domains considered. The corresponding time scales vary from years to hours. Gravity field mapping, for example, requires repeated determination once or twice per decade, whereas the investigations of short-term variations in the Earth's rotation rate approach time scales as short as hours. These examples may help to explain the difficulties encountered in defining programs that satisfy a maximum variety of Solid Earth Sciences. These challenging requirements can only be met through the coordinated definition of the different observation programs. Given the oft conflicting requirements of the various disciplines, there is the risk that attempts to combine several disciplines within the programs of any one agency or nation or even on a single spacecraft will compromise on the characteristics and requirements of each and, in addition, will exceed the financial possibilities of the planning agency. Furthermore, in order to exploit the full scientific and technical competence of the international community and, at the same time, reduce the costs of a program through sharing of development work, facilities and operations, NASA is invited to examine for each element of the proposed Solid Earth program the possibilities of joint international efforts in the forms of contribution of hardware, operational support or data analysis and interpretation. Joint campaigns for sensor calibration and data validation are just two examples for such international cooperation.

## **3. Past Experience and Current Status of International Cooperation**

Except for remote sensing, where international coordination is somewhat limited, apart from some areas such as data formats, data dissemination and calibration experiments, the space geodesy community has been forced to set up multi- and international tracking programs from the very beginning of the space age.

In the mid-seventies cooperation returned to a multilateral situation. Examples of the valuable multilateral activities of this period are the tracking of the U.S. altimeter satellites GEOS-3 and SEASAT. The usefulness of radar altimetry data from both of these spacecraft was greatly improved by the deployment of additional, temporary Doppler tracking receivers at various sites around the world and laser tracking by non-U.S. systems.

International cooperation improved quantitatively and qualitatively with the implementation of the Crustal Dynamics Project (CDP) at Goddard Space Flight Center (GSFC) in 1979 and the reorganization of a Commission on the International Coordination of Space Techniques for Geodesy and Geodynamics (CSTG) in 1980 as a joint commission of the International Association of Geodesy (IAG) and the Committee on Space Research (COSPAR) of the International Council of Scientific Unions (ICSU). The Crustal Dynamics Program established cooperative arrangements with over twenty countries. The CSTG has initiated and coordinated various international observation campaigns through its subcommissions

for VLBI, SLR and GPS tracking techniques and CSTG projects and is still doing so. One of the best examples of a cooperative international program was the MERIT (Monitoring of Earth Rotation and Intercomparison of Techniques) program with its two international observation campaigns in 1982 and 1984. Through MERIT, and based on its results, the International Earth Rotation Service (IERS) was formally established in January 1988. Composed of global network tracking stations, coordination centers and international analysis and archiving centers the service has been functioning well since its establishment and can be taken as a good example of the sharing of international operations and organization. A similar approach is under consideration by the CSTG GPS Subcommittee for the maintenance of a terrestrial reference frame and the generation of Earth orientation parameters for the handling of geodetic GPS requirements within the IERS. The objective is to establish centers for the acquisition and dissemination of data, as well as for standardized GPS orbit calculations and product generation as an extension to the existing CIGNET.

Regional international cooperation in the measurement of crustal deformations was first done under the WEGENER-MEDLAS Project in the Mediterranean region. Beginning as a loosely organized group of NASA scientific investigators in Europe, WEGENER has grown into a well coordinated international project with 30 European, African, Asian and North American institutions from 14 countries being directly involved. In the meantime this project has received the endorsement of the ICSU Inter-Union (IUGG & IUGS) Commission on the Lithosphere (ICL), the Council of Europe and of CSTG. The WEGENER Project has started to expand in several ways in the last two years. GPS densification measurements are being carried out in various areas of the Mediterranean by varying combinations of US and European groups and these measurements are being repeated at regular intervals. A link connecting the WEGENER Project with the IDEAL Crustal Dynamics Project of the InterCosmos group is under discussion.

Cooperative GPS measurements were carried out in the Caribbean, Andean South America and the South West Pacific by JPL in cooperation with partners from Europe, South America and Canada. Similar bilateral and multilateral arrangements to conduct deformation studies using GPS techniques are being prepared between Australian, European, Japanese, U.S. and U.S.S.R. groups and potential partners in China, India, Indonesia and Papua-New Guinea. Cooperation is also developing between some of these countries in the field of VLBI.

#### **4. Cooperation in the 1990's**

Scientific research in the area of Solid Earth will be dictated primarily by the large international programs until far into the 21st century:

- the International Decade for Natural Disaster Reduction (IDNDR)
- the International Geosphere-Biosphere Program (IGBP)
- the International Geological Correlation Program (IGCP)
- the International Lithosphere Program (ICL) which includes projects aimed at making significant contributions to the IDNDR and IGBP, namely:

- the Instability of Megacities
- Risk Assessment of Volcanic Hazards
- Global Geoscience Transect Through Hazardous Regions
- Real Time Tectonics
- Terrestrial Observatories

Additional impetus is expected to come from environment-related programs such as:

- the World Climate Research Program (WCRP)
- the Global Change Program
- the Tropical Oceans and Global Atmosphere Program (TOGA)
- the Tropical Oceans Circulation Experiment (WOCE)

as well as through special programs such as the International Space Year (ISY) and others. These large programs have become known to the public, to political planners, and to decision-making committees and should thus become the driving forces for Solid Earth Science Programs insofar as both multi-disciplinary engagement and budgetary aspects are concerned.

Two further aspects influence the financing and realization of Solid Earth Programs and therefore also international cooperation, be these defined by NASA or other (also non U.S.) agencies. These are the Polar Platforms currently being prepared by the Space Station partners (NASA, ESA, Canada and Japan) and the definition of new climatological and environmental programs and their accompanying budgetary requirements. These systems offer opportunities for Solid Earth Science, but they also bring with them certain risks. The opportunities offered by these systems comprise primarily the limited possibility to fly internationally coordinated SES instruments. These include for example the Geodynamics Laser Ranging System (GLRS), the Geoscience GPS Instrument (GGI), PRARE-extended (PRAREE) and remote sensing systems. The joint internationally sponsored and coordinated use of such systems can contribute significantly to the achievement of the objectives defined by the JDNHR, JCL and other major international programs.

On the other hand, the dangers implied by these systems lie in the risk of one-sided orientation towards climatological and environmental (C and E) research, or alternatively, the reduction of space for SES instrumentation to an unacceptable minimum. To these comes the risk that C and E research is considered to be of such overwhelming importance that budgetary limitations are set on SES research.

The first of these risks can only be averted by well coordinated and well founded pressure to fly SES instrumentation on EOS A/B and EPOP 1/2. The second problem touches on the more general aspect expressed in the necessity for an increased coordination of international cooperation in the Solid Earth Sciences. In many countries there is a probability that funding for SES research will be reduced (or maintained at its current level) in favor of WCRP, IGBP and other climatological/atmospheric programs. This probable tendency can only be overcome by spreading the load through international cooperation if SES research is to be significantly advanced.

Areas of cooperation which would enable the cost of SES to be shared more equitably can be defined, with the objective of reducing cost to the individual state or agency without sacrificing the integrity of global and regional solutions to the urgent problems to be solved. These include:

- (i) Cooperation in the installation and operation of ground tracking facilities for the different observing techniques. There are enough countries in the world which, with good will, can participate in the realization of those networks (SLR, VLBI, GPS, DORIS, PRARE) which are necessary for the achievement of the objectives of SES.
- (ii) Collaboration in spaceborne instrumentation and missions. High resolution geopotential and topography mapping missions are a typical example of highly complex and expensive missions. Their output is fundamental to Solid Earth Sciences and their products serve the local international geoscience community. There is no reason why one agency or country should carry the financial burden of such missions. Bilateral or multilateral cost-sharing is more satisfactory, even if the share of each partner is not equal. There exist already examples of such bilateral arrangements in Solid Earth Sciences such as the joint USA/Italy Lageos 2 Satellite. The ARISTOTELES mission, under definition by ESA represents a good opportunity to exploit a broad international effort for the realization of a zero order gravity gradiometer mission. A similar approach could be followed later on in this decade for a first order gravity gradiometer mission, such as SGM.

Similar approaches in sharing payload and/or mission costs are applicable to a topography mapping mission (TOPO) and a volcanology mission such as OVO.

- (iii) Access to observational data and data handling. It is important to realize that very large amounts of data will be produced by future space missions and microwave systems in densification areas in order to meet requirements for higher spatial and spectral resolution and repetitive measurements. This will require a major international effort in data handling. In the framework of each program data collection, distribution and archiving procedures will have to be agreed upon, whereby the emphasis is to be placed on easing accessibility on the part of the international community. International arrangements for the establishment of large, regional multidisciplinary data bases are a requirement of the near future.

It is clear that political and economical developments can have negative impact on the quality and continuity of cooperative bilateral or multilateral activities. It would, however, be wrong policy to use this argument as a leading criteria when establishing long term programs which could most cost effectively be implemented by incorporating elements of international cooperation.

In this spirit NASA should perhaps also consider an intensified collaboration with the international partners along the items (i) and (iii).

## 5. Recommendations

### The International Programs Panel

- **Expresses** satisfaction that the NASA Solid Earth Science Planning Conference **recognizes** the importance of international cooperation and international programs.
- **Believes** that Solid Earth research needs and will greatly benefit by the organization of appropriate international programs, with NASA participation, and well defined objectives, procedures, and responsibility between partners.
- **Suggests** that all efforts should be made to relate and coordinate the activities of the different Solid Earth Science projects (including NASA's) with the relevant major international programs through the established international bodies such as the INTERNATIONAL DECADE OF NATURAL DISASTER REDUCTION (IDNDR), INTERNATIONAL GEOSPHERE-BIOSPHERE PROGRAM (IGBP), INTERNATIONAL LITHOSPHERE PROGRAM (ICL) and others.
- More specifically, based on discussions and exchange of experience between the members, the panel **recommends:** that NASA participates and takes an active role in:
  - (1) the continuous monitoring of existing regional networks such as the WEGENER-MEDLAS networks to investigate real time tectonics and the extension of such networks to other critical areas of important tectonic activity, such as the Sindh-Burmese-Himalayan area, the South East Asian islands and the Andes; furthermore such networks should be extended to cover active volcanic zones;
  - (2) the realization of high resolution geopotential and topographic missions;
  - (3) the establishment of interconnection of the reference frames as defined by different space techniques (SLR, LLR, VLBI, GPS, PRARE, DORIS). Emphasis should be placed on providing sufficient stations on the Southern hemisphere for all systems;

- (4) the development and implementation of automation for all ground-to-space observing systems;
- (5) calibration and validation experiments for measuring techniques, including remote sensing, in support of Solid Earth Science. Similar efforts should be developed for the validation and calibration of data;
- (6) the establishment of international space-based networks for real-time transmission of high density science data in standardized formats;
- (7) tracking and support for non-NASA missions;
- (8) the extension of state of the art observing and analysis techniques to the developing countries.

The International Panel **recognizes** the importance of the proper education and training for the success of Solid Earth Science Programs and **urges** NASA to **participate** in the organization and implementation of courses, seminars, and training programs especially for the developing countries.

Finally, the International Panel **stresses** the extreme importance of the use of the proper monumentation and accompanying documentation for the studies of the Earth's geometry, kinematics and dynamics.

## **APPENDICES**



## APPENDIX 1

**Country:** Australia

**Objectives:** Australia has a wide range of activities in the disciplines covered by NASA's Solid Earth Science Program. These match all of the major scientific objectives developed by the various scientific panels in this meeting and involve space-based measurement as an integral component. Only these space-based issues are discussed below.

### **Program Elements:**

#### **Observing Programs:**

- VLBI - facilities exist at Parkes and the Australian Telescope as well as at NASA's Tidbinbilla site. A cooperative program exists between the University of Tasmania and the U.S. National Geodetic Survey.
- GPS - support for international programs and comparison with VLBI sites
- Laser Ranging - based at Ororral Valley, support for international geodynamic and oceanographic objectives. Support is also given to NASA's laser tracking facility at Yarragadee (Western Australia).
- Satellite Remote Sensing - Landsat, MOS-1, meteorological satellites, based at Alice Springs
- Aircraft Remote Sensing - multispectral scanner systems, mid-infrared laser reflectance spectrometer
- Monitoring crustal motions in Papua/New Guinea to determine the deformation between the South Bismarck Sea, the Solomon Sea, the Woodlark Basin, and the Papuan Peninsula

#### **Current International Activities:**

- Comparison of long GPS baselines with laser and VLBI baselines
- VLBI source catalogue improvements

- Precision vertical datum for altimetry studies
- Analysis of remote sensing imaging acquired as part of the C130 mission to Australia
- Comparison of the TIMS and Mid-infrared Laser Reflectance Spectrometer data

## **APPENDIX 2**

**Country:** Canada

**Area:** Space Geodesy and Geophysics

**Objectives:**

- Application of GPS and VLBI to determination of crustal motion and to monitor earth's rotation
- Investigation of global dynamics by superconducting gravimetry
- Establishment and maintenance of VLBI reference system
- Investigation of the geoid, sea level and ice dynamics
- Delineation of contemporary postglacial rebound and sea level change
- Assessment of west coast seismic hazard

**Program Elements:**

- GPS/VLBI measurements of crustal deformation
- GPS orbit determination
- Participation in SEDI
- Planned participation in IERS monitoring
- VLBI terminal and correlator development
- Tracking of GEOSAT and analysis of altimetry data
- Planned tracking and applications of ERS-1, SPOT-2, TOPEX, EOS polar platforms
- Postglacial rebound monitoring (GPS, VLBI, absolute gravimetry)
- GPS and absolute gravimetry monitoring of Cascadia subduction zone for earthquake hazard assessment
- Geophysical applications of visible, infrared and radar imagery

#### **Current International Activities:**

- CIGNET GPS network
- NGS/NASA cooperative VLBI at Algonquin Radio Observatory and "mobile" sites
- UNAVCO GPS network
- GOTEX 1 campaign
- Casa Uno and Iceland campaign
- Proposed IERS participation by ARO
- Superconducting gravimeter network participation
- Development of instrumentation for Soviet Radio Astron. Project
- Participation in international absolute gravity base-station network
- Participation in TRANET, DORIS and PRARE tracking networks

#### **Current and Future Cooperative Programs:**

- Proposed NASA GLRS observations along Cascadia subduction zone
- Cooperative crustal deformation monitoring with NASA in Alaska/Yukon area and proposed extension to Cascadia subduction zone
- International GPS campaigns and global tracking network
- U.S./Canada cooperation in postglacial rebound and NA plate stability
- Geophysical satellite tracking
- RADARSAT

## **APPENDIX 3**

**Country:** Federal Republic of Germany

**Objectives:**

- Understand the evolution, structure and dynamics of the European Lithosphere-Asthenosphere system
- Monitoring of Earth orientation and maintenance of reference frames
- Assistance in monitoring global sea level
- Modelling of global and regional geopotential fields
- Investigation of ice dynamics
- Investigations of global and regional plate motions and deformations
- Earthquake hazard assessment
- Remote sensing of the national territory and other regions (e.g. Antarctica)

**Program Elements:**

**Current:**

- Fundamental Station Wettzell SLR, VLBI, GPS, TRANET, superconducting gravity meter, broadband seismometer
- Mobile laser MTLRS - 1
- WEGENER/MEDLAS Project: regional and continental
- GPS surveys
- Analysis of SLR, VLBI, GPS, Doppler, gravity and magnetic data
- Absolute & superconducting gravity meters
- DEKORP deep seismic sounding

- Magneto-telluric sounding and deep continental drilling
- Stress measurements in deep boreholes, from fault plane solution and overcoring
- L/C/X band receiving antennas
- MOMS, metric camera
- Antarctic SAR/VLBI antenna
- Precise Range and Range Rate Equipment (PRARE(E))
- MOMS-02, XSAR

#### **Current International Activities:**

- Bilateral:
- Measurement of VLBI baselines
  - Wettzell-Madrid-Hartebeesthoek-Shanghai
  - Anatolian Fault motion studies (TCGG)
  - Superconducting gravity measurements at Richmond, Florida (USNO/IfAG)
  - Mobile VLBI campaign in Europe (NGS/IfAG)
  - Development of a new absolute gravimeter (NGS/IFAG)
  - IRIS and intensive VLBI measurement (NGS/IfAG)
  - TRANET Doppler measurements and Wettzell (DMA/IfAG)
  - Gravity field modelling (GRGS/DGFI)
  - Calabrian Arc Project (Univ. Bologna/DGFI)
  - Bocono Fault Project (Univ. Maracaibo/DGFI)
  - CASA Project (JPL/DGFI)
  - Space data analysis (SRC Warsaw/DGFI)
  - SLR data analysis (AC Moscow/DGFI)
  - ERS-1 Processing and Archiving Facility (ESA/DLR/DGFI)

**Multilateral:**

- CDP laser and VLBI measurements in Wettzell
- WEGENER/MEDLAS laser measurements in the eastern Mediterranean
- MEDLAS densification in the Aegean and Tyrrhenian
- CIGNET-GPS tracking
- EUREF-GPS measurements in western Europe
- European Laser Data Collection Center
- PRARE network deployment
- European Geotraverse

**Future Plans for Cooperation:**

- Installation and operation of SAR/VLBI receiving station at the Antarctic Peninsula (Esperanza) from summer 1990/91 onwards for the ERS-1 mission
- Operation of PRARE system for ERS-1 (1991 onwards)
- Development of PRAREE system for Polar Platform System (1989 onwards)
- Development and operation of a transportable integrated measuring system at sites in the southern hemisphere
- Calibration of USSR SLR system(s)
- Development and operation of gravity mission with InterCosmos (SAGSAT/1993-95)
- MOMS-02 Shuttle flight (1993)
- XSAR Shuttle flight (199?)

## APPENDIX 4

**Country:** France

**Area:** Solid Earth related space activities managed by CENTRE NATIONAL D'ETUDES SPATIALES (CNES)

**Objectives:** Understand the dynamics of the Earth and determine its internal and surface structure and evolution. This includes:

- Land topography, tectonics, geology, geomorphology
- Crustal motions in seismic and volcanic area
- Gravity field modelling, temporal variations, Earth and ocean tides, crustal structure
- Oceanic lithosphere dynamics, plate motion
- Magnetic field modelling: core, lithospheric, ionospheric and magnetospheric
- Core dynamics, mantle conductivity
- Mantle convection

**Program Elements:**

- Scientific investigations: geodesy, remote-sensing, geopotential, altimetry, planetology
- Space geodetic measurement and analysis: SLR, LLR, RF tracking (TRANET, DORIS, GPS), altimetry
- Remote sensing: SPOT, TM
- Stratospheric balloon surveys
- Development of gravity gradiometry technology



### **Current International Activities:**

- Approved programs and missions:
  - SPOT 1, 2, 3, 4
  - DORIS (on SPOT 2,3,4, TOPEX, POSEIDON)
  - GPS
  - STELLA + ultra-mobile laser station
  - LLR
  - TOPEX/POSEIDON (altimetry + DORIS)
  - GEOSAT 1,2 (Doppler, laser tracking, altimetry)
  - MARS OBSERVER
  - MARS 94
  - MAGELLAN
- Related ground activities:
  - Seismic tomography
  - Surface observatory (INTERMAGNET, GEOSCOPE, LITHOSCOPE)
  - ODP
  - Numerical modelling
  - Laboratory experiments and measurements (deformation, high P/T materials, geochemistry, magnetic properties,... )
  - Magsat data analysis

### **Future Cooperative Programs:**

- MFE/MAGNOLIA
- GRADIO/ARISTOTELES
- Geophysical data collection and distribution

## APPENDIX 5

**Country:** Greece

**Objectives:**

Greece is a country of high tectonic activity, and as a result a great effort is being made to understand the mechanisms of tectonic motions and earthquakes.

The fact that Greece is a sort of natural laboratory for tectonic and earthquake research creates a lot of international interest, and as a result several bi/multi/international programs have been developed. All these programs are coordinated by the Hellenic National Committee for Geodesy and Geophysics.

**Program Elements:**

Space techniques for geodesy and geodynamics have been used for a long time in Greece. The Dionysos Station has been operating since 1967 and has participated in most of the relevant international programs. As a matter of fact, most of the space activity in Greece has been in connection with international programs.

Today, the measurement and interpretation of crustal motions with the use of SLR and GPS techniques are being emphasized.

**Current International Activities:**

Greece participates in the WEGENER/MEDLAS program with 6 SLR sites. Measurements were made in 1986, 1987, and 1989.

Since 1987, 6 GPS networks for monitoring crustal movements have been established through international programs with the participation of groups from the USA, UK, Germany, Switzerland, and the Netherlands. One hundred and forty-four (144) monitoring sites have been carefully selected and monumented. These cover most of the country, with a larger number of sites in Central Greece. One hundred and thirteen (113) points have already been measured once, while the remaining 31 will be measured this September. The networks are interconnected and tied to the SLR network.

**Future Plans for Cooperation:**

It is anticipated that the already established network of sites will be remeasured at about 2-year intervals. New networks, or extensions of existing ones, are being considered, but the current workload is already quite high while funding is quite low.

## **APPENDIX 6**

**Country:** India

**Objectives:** To model the evolution, structure and dynamics of the Indian lithosphere and the subjacent mantle in a planetary perspective.

**Program Elements:**

- current
  - in preparation
- Geopotential fields
- Deep seismic soundings
- Wide-band magneto-tellurics
- Isotope and trace element chemistry of mantle-derived rocks
- Seismic tomography
- Earthquake hazard assessment
- In-situ stress measurements
- Theoretical frameworks for modelling
- SLR, VLBI, and GPS studies:

**Current International Activities:**

**Bilateral:** International cooperation exists in varying measure in all the ongoing programs, but these are limited to opportunities for joint work provided by exchange visits of scientists under bi-lateral programs:

- Isotope chemistry - UCSD
- Seismic tomography - USGS
- Modelling frameworks - CNRS
- In-situ stresses - FRG
- Earthquake hazard - IPE, USSR-AS

- Intense deformation zone of central Indian Ocean - Institute of Oceanology, USSR-AS

#### **Current and Future Cooperative Programs:**

An international cooperative program to initiate SLR, VLBI and GPS studies towards constraining inter-plate velocities and intra-plate deformation is still under discussion, especially concerning the fabrication and installation of the antenna and Mark III recorder. Meanwhile, steps have been taken to develop the front-end and down-converter systems, as well as a hydrogen maser. Joint synchronous experiments with FRG, Japan and USSR have also been agreed to in principle.

## **APPENDIX 7**

**Country:** Indonesia

**Objectives:**

Indonesia is a country of active deformation:

- Meeting of 3 global tectonic plates: Indo-Australian plate, Eurasian plate and Pacific plate with all the 3 characters: convergence, subduction and spreading
- Forming of island arcs
- High volcanic activities (108 active volcanoes)
- High seismicity - frequent large earthquakes along plate margins

The active deformation of the Earth's crust in this part of the world exposes Indonesia to frequent natural hazards which cause the destruction of human life and infrastructures. A national program has been set up for mitigation of natural hazards: earthquakes, volcanic eruptions, tsunamis, etc.

Within the scope of this national program an international cooperation is sought to support the national objectives with due consideration of the transfer of technology, especially the application of space technology to monitor the dynamics of the Earth's crust and its impact on the environment.

**Program Elements:**

- Study of regional deformation and strain accumulation in relation to earthquakes along the tectonic plate margins
- Study of tides and tidal phenomena as well as the ocean dynamics (INSTEP = Indonesian Sea Through Experiments) due to flow of waterbodies from the Pacific to the Indian Ocean
- Application of remote sensing to monitoring volcanic activities

### **Current International Activities:**

1. Indonesia - USA (U.S. National Science Foundation) - Japan (Earthquake Research Institute of the Univ. of Tokyo) - Australia (Univ. of New South Wales)
  - GPS observations along the Sumatra Fault System (the oblique plate convergence between the Indo-Australian plate into the Eurasian plate) and the subduction of the above mentioned plates in the southern part (Java trench)
  - 14 receivers deployed to observe 60 stations from 22 August to end September 1989
  - Code name: GPS-GPS (Global Positioning System for Geodynamic Project of Sumatra)
  - A project of 5 years repeated at 2 years' interval; for the subduction part - annual repetition
  - Includes transfer of technology to Indonesian scientists in GPS network observations and data analysis
  - Australia will observe at Christmas Island and Yarragaddee (VLBI station)
2. Bilateral cooperation between Indonesia and the Netherlands within GPS-GPS campaign, gravity observations will be carried out
  - First order gravity network in Sumatra
  - Establishing a calibration line in Java
  - Observations of gravity profiles along levelling lines in Sumatra, Java (completed), Kalimantan, Sulawesi
3. Bilateral cooperation between Indonesia and Australia on tides and tidal phenomena
  - Establishing a network of tidal stations to support the ASEAN Project on Tides and Tidal Phenomena
4. Bilateral cooperation between Indonesia and the USA (US-DMA)
  - Airborne geomagnetic survey in the straits of Macassar and Sunda

### **Future Plans for Cooperation:**

- Cooperation with neighboring countries for establishing a network of fiducial stations for GPS observations
- Require assistance for establishing a network of absolute gravity stations (hardware requirement)
- Upgrading of tidal stations for satellite data transmission/telemetry to national database center and to World Oceanic Data Center. If these stations are upgraded, they can be used for tsunami early warning system
- Telemetry of volcanic activities and its integration with seismic network stations
- Involvement in Spaceborne Radar (SAR) mission for topographic mapping, due to cloud and haze problems in tropical area, when using optical system
- Involvement in ERS-1 tracking (PRARE)

## **APPENDIX 8**

**Country:** Italy

**Objectives:**

The National Research Council (CNR) has established a national program in Solid Earth Geophysics. The activities connected to space are mainly addressed by ASI ( Italian Space Agency). For geodesy and geodynamics in the 90's ASI is planning to establish a multidisciplinary program oriented to Earth observation. This program will be similar to other Agency programs (e.g. the NASA Mission to Planet Earth) and will be connected to major global efforts such as the Long Term Change Monitoring Program. In this framework projects related to the use of space-based techniques for regional and global geodynamics studies, geopotential and magnetic field, lithosphere structure and evolution, land cover monitoring, long term change monitoring are envisioned. This program will comprehend experiments, theoretical studies, but also development of new sensors, spacecraft and ground stations. These techniques will possibly be applied to planetary exploration.

**Program Elements:**

- Space geodesy and geodynamics
- Remote sensing

**Current International Activities:**

- LAGEOS II Project (ASI/NASA)
- Tethered Satellite System (ASI/NASA)
- STS based SAR-X system (ASI/DLR/NASA)
- Maintain at Matera a fundamental station with permanent colocation of major precise positioning techniques (SLR, VLBI). Cooperation exists with NASA with regard to participation in major observing programs and technological upgrade.
- Two VLBI stations (Medicina, Noto) are partially devoted to space geodesy measurements in IRIS, both equipped with prime focus S/X receiver are operated by the Institute for Radioastronomy of the CNR.



- Cooperation with NASA for the development of new laser ranging systems and for the operation of the fixed system at Matera.
- Participation in the WEGENER consortium activities. Six standard pads have been constructed (Lampedusa, Milo, Basovizza, Cagliari, Medicina, Matera) for mobile Laser systems operation and colocation with other instruments.
- Densification of the MEDLAS network by means of GPS in the central-southern Mediterranean (Univ. of Bologna/DGFI).

#### **Future Cooperative Programs:**

- LAGEOS III mission under consideration (ASI/NASA)
- Establish an international effort for processing, archiving and distribution of LAGEOS II and III data
- Establish a permanent GPS network in Italy (SLR and VLBI sites) to support the global tracking network
- Extend the existing cooperation on SAR development (SAR-X) to aspects related to data archiving and processing
- Under evaluation: the opportunity of bilateral remote sensing missions for monitoring volcanoes
- Under evaluation: an Italian participation in the Aristoteles mission.

## APPENDIX 9

Country: Japan

### Objectives:

Solid Earth related activities in Japan correspond to its specific geographic location as follows:

1. Establishment of the marine geodetic control networks based on satellite geodesy, comprising three stages:
  - Connection of the Tokyo Datum to the world geodetic system based on SLR observations of Lageos and other geodetic satellites
  - Connection of principal islands to the Japanese mainland based on SLR observations of Ajisai and LAGEOS by using fixed and transportable systems
  - Connection of islands to the principal islands by using geodetic observations of the navigation satellite systems, NNSS and GPS.
2. Observation of the global plate motion by using SLR and VLBI techniques including the Antarctic Continent.
3. Observation of the polar motion and the Earth's rotation parameters by using SLR and VLBI techniques.
4. Detection of regional crustal deformations by using GPS technique for the purpose of predicting earthquakes and volcanic eruptions.
5. Application of satellite altimeter data for detecting the precise geoid, gravity anomaly field, crustal structure, sea bottom topography, ocean dynamics, ocean tide, etc. To obtain precise altimeter data SLR is used to track altimeter satellites and to calibrate altimeters.
6. Precise marine positioning on the sea surface and on the sea floor based on GPS technique.
7. Improvement of the geopotential field in the Northwestern Pacific region based on the terrestrial and aerial observations introducing existing and future satellite-based data.
8. Volcano observations using LANDSAT and MOS-1 data.

9. Detailed land topography and geological observations by using SAR data (RADARSAT, JERS-1).
10. Researches on formation of back-arc basins, deep structure of the ocean lithosphere, collision of tectonics in South Fossa Magna, structural evolution of the Japanese islands and formation and evolution of the lithosphere, which were conducted under the International Lithosphere Project (ICL).

Improvements in data analysis techniques and hardware development (SLR, VLBI, GPS, etc.) are also required to achieve the above objectives.

#### **Current International Activities:**

Various Solid Earth related activities are being conducted through bilateral, multilateral, and international cooperation:

- **CDP:** SLR and VLBI observations are being conducted in cooperation with NASA within the framework of the Crustal Dynamics Project. Data and information exchange has been successful, and cooperation is quite successful.
- **IERS:** Simosato SLR station and Kashima VLBI station are acting as the observation stations of IERS. The National Astronomical Observatory (NAO) is acting as a full-rate VLBI data analysis center for IERS. NAO is also acting as the IRIS-P network center.
- **Ajisai Observation:** The Japanese geodetic satellite "Ajisai" was launched into a rather low orbit and it flashes brightly. It is easy to observe Ajisai by using a small SLR system. Ajisai observations are being achieved through bilateral cooperation.
- **ERS-1 and TOPEX/Poseidon:** Satellite altimetry is a very effective technique for geodetic, geophysical, and oceanic investigations. Japan has proposed studies using ERS-1 and TOPEX/Poseidon data. SLR observations of the altimeter satellites will be made in order to obtain precise orbits and calibration of altimeters.
- **Plate Motions by VLBI:** Joint bilateral experiments are being performed by Japan and China, Canada and Australia.
- **DELP:** The Japanese national program for the International Lithosphere Project has operated from 1985-89.

### **Future Plan for Cooperation:**

It is desirable to maintain and improve international cooperation on current activities to achieve the initial objectives. Cooperation on hardware improvement and on the establishment of newly developed hardware is also required. Cooperation on satellite tracking and data collection for ERS-1 and TOPEX/Poseidon satellites will be established. The cooperation of related countries may be desirable for some regionally intensified projects in the region of Eurasia and the Western Pacific where tectonic activities are quite strong.

The Japanese remote sensing satellites JERS-1 and ADEOS are scheduled to be launched during the 1990's. International AO sensors will be installed on board the ADEOS.

Data exchange in Earth science will become very important in the future, and some international data base systems based on advanced computer and communication technology will need to be organized. The data base needs to be open in principle to all potential users.

## APPENDIX 10

**Country:** Peoples' Republic of China

**Objectives:**

1. Tectonic motion

- Global plate motion and regional crustal deformations especially in seismically active regions
- Research: mechanism of the driving forces of plates
- Application: earthquake prediction
- Measurements: via VLBI, SLR, GPS and seismological, geologic means

2. Space geodesy

- Precise 3-D national geodetic network and participation of global terrestrial reference system
- Measurements: via VLBI, SLR, GPS

3. Geopotential field

- Upgrade the local geopotential field and fill the gap of the global data
- Measurements: via SLR and gravimeters (superconducting and classical)

4. Earth rotation and related topics

- Monitor and conduct research on the variations of Earth rotation, explore the correlations of these variations with some geophysical phenomena, and the reactions of the solid, oceanic, atmospheric Earth
- Measurements: via SLR, VLBI

5. Mean sea-level monitoring

- by using VLBI and GPS, connect the tide gauges to the global terrestrial reference system

6. Remote sensing of the Solid Earth through satellites and apply findings to many fields.

To meet the above mentioned objectives, a VLBI network including Shanghai (operational), Urumqi, and Kunming is being developed, along with an SLR network including Shanghai, Wuhan, Chang-chun (operational at present), Beijing, Kunming (in 1990) and Urumqi (planning stage). The GPS and gravimetry campaigns are being organized. The participating institutions are:

- Chinese Academy of Sciences

Shanghai Obs, Yunnan Obs, Urumqi Station, Chang-Chun Station, Institute of Geology and Geophysics (Wuhan), etc.

- State Seismological Bureau

Institute of Geology (Beijing), Institute of Seismology (Wuhan)

- State Survey and Mapping Bureau

Institute of Survey and Mapping (Beijing), University of Survey and Mapping (Wuhan)

- State Administration of Oceans

Involved in mean sea-level monitoring and remote sensing.

#### **Current International Cooperation:**

1. Plate Motion

Shanghai VLBI and SLR stations are participating in the CDP and cooperating with Kashima, Simosato, Wettzell, etc. for baseline measurements.

2. Earth Rotation

Shanghai Observatory is one of the data analysis centers in IERS for the global VLBI, SLR, LLR data.

Shanghai and Wettzell are conducting an intensive ERP program one month/year in 1989-1991 via VLBI

### **Future Plans for International Cooperation:**

#### **1. Earth Rotation**

More involved in IERS for terrestrial reference system. Earth rotation monitoring data analysis and research.

#### **2. Plate Motion**

Continue the CDP, join the Eurasian-Pacific region project conducted by USSR, India, Japan, and related countries.

#### **3. Join the mean sea-level monitoring program.**

#### **4. Join the global tracking of TOPEX, ERS-1, etc.**

## **APPENDIX 11**

**Country:** Sweden

**Area:** Space Geodesy

**Objectives:** Participate in NASA Solid Earth Program with VLBI and ESA/NASA satellite programs. A national GPS group with 4 receivers has been formed for regional geodetic studies. Development of a water vapor radiometer (WVR) for extensive mapping of tropospheric variations for calibrating precise baselines.

### **Program Elements:**

- Monthly scheduled geodetic VLBI measurements (20/yr) at ONSALA.
- Altimetry experiments "Arctic Geodynamics" on ERS-1, TOPEX/Poseidon
- GPS regional geodetic studies and tectonics
- Consideration of joint geodetic VLBI station in Chile, together with W. Germany and U.S.
- Post glacial rebound related to sea level, ice and geodynamics studies.

### **Current International Activities:**

- Participation in IRIS/VLBI Network
- Participation in GPS experiments in Scandinavia and Arctic
- Altimetry for gravity and tide studies in the Baltic and Norwegian Sea and Arctic Ocean

### **Current and Future Cooperative Programs:**

- Potential of operation of Chilean VLBI site
- GPS cooperative projects



- Future gravity field mission participation
- ERS-1 "Arctic Geodynamics Project" with U.S. and Canadian participants.

## APPENDIX 12

**International Agency: InterCosmos**

### **Objectives:**

The main objectives of the InterCosmos program in the field of space geodesy and geophysics are:

1. Space Geodesy: stations positioning, geodetic reference frames.
2. Geodynamics:
  - Global and regional tectonics, plate and intraplate deformations
  - Global gravity field improvement: separate resonant harmonics, low-degree terms.
  - Earth rotation parameters.
3. Thermosphere Model Improvement

### **Program Elements:**

1. Taking into account that accurate knowledge of satellite orbits is a key question for solving all above-mentioned problems, a network of satellite tracking stations is permanently extending. At the present time, 9 laser stations are in operation. The II generation laser systems SBG (20 cm), Crimea (6-20 cm), ULIS-630 (20 cm) and others are being used.

The mobile laser system ULIS-M is in preparation.

2. The project IDEAL - Investigation of Deformations of Eurasian Lithosphere: A combination of terrestrial and space methods for plate deformation studies along the plate boundaries and Alpine-Asiatic mountain belt.
3. The joint programs of laser ranging of different geodetic satellites (Lageos, Starlette, Ajisai,...) and Doppler campaigns for station positioning.
4. Two Soviet passive geodynamic satellites, Etalon 1 and 2 with laser retroreflectors, were launched in 1989 into the near circular orbit with an inclination of  $64^{\circ}8'$  and semiaxis of 25,500 km.

5. The geodetic satellite GEO-IK was put into orbit on May 30, 1988 with the orbital parameters:  $h \sim 1,500$  km,  $i = 74^\circ$ . The satellite is equipped with a Doppler transmitter, a flashlight system, and laser corner reflectors and is supposed to be used for gravity field improvement and regional geodetic networks.

6. Dedicated VLBI - network "Quasar" aiming at:

- Constructing and coordinating a reference system based on extragalactic radio sources
- Determining and monitoring Earth rotation parameters
- time synchronization.

The network will consist of 8 antenna systems with a diameter of 32 m (for radio sources), 8 antennae of 1.3 m for navigation satellites. The scheme of proposed sites for antennae is attached.

The time schedule of network construction is 1992 - first two antennae, and 1995 - experimental tests of full network.

7. Developing the navigational GLONASS system (now 10 satellites in orbit) and improvement of the positioning accuracy.

8. Project "System of Aeronautical Satellites" (1993)

Collection of new experimental data about the state of the upper atmosphere in a wide range of helio-geophysical conditions and improvement of the existing models, mainly at altitudes of 200-500 km (sensitive microaccelerometer, mass spectrometer, and complex of instruments for measurements in the ionosphere).

#### **Current International Activities:**

- IERS (SLR and data analyses)
- WEGENER (SLR and data analyses)
- CDP-NASA - (input of SLR data)
- DORIS - CNES (beacon-antenna at Yuzhno-Sachalinsk)
- LASSO (ESA)
- Satellite laser tracking in India (ISRO)

### **Future Plan for Cooperation:**

#### **1. WEGENER - IDEAL**

SLR and calibration of Soviet laser systems (DGFI and IfAG, West Germany).

#### **2. IERS (SLR, LLR, and VLBI), data analyses**

#### **3. ERS-1 - laser tracking, data analyses**

#### **4. Plate deformation investigation program in Asia (IDEAL Project with Indian and Chinese participation).**

### **Proposal to NASA:**

Cooperation of the CDP and IDEAL projects in Asia: SLR of the Lageos and Etalon satellites and GPS network.

INTERCOSMOS SIR NETWORK: as of July 1, 1989

1181 - Potsdam, GDR

1953 - Santo de Cuba, Cuba

1884 - Riga, USSR

1873 - Simeiz, USSR

1893 - FIAN, USSR

7811 - Borowiec, Poland

1148 - Ondrejov, Czechoslovakia

1101 - PLANA, Bulgaria

1901 - Helwan, Egypt - CSSR

## APPENDIX 13

**International Agency:** European Space Agency

**Objectives:**

- Development of the space segment for scientific and applications missions.
- Build the corresponding space transportation system, together with the necessary ground infrastructure.
- No mandate in data analysis and interpretation.

**Program Elements (in earth observation only):**

- European Remote Sensing Satellite Program ERS-1, to be launched September 1990 for ocean, ice, coastal zone investigations by microwave remote sensing techniques.
  - SAR (swathwidth 100 km, resolution 30 m).
  - Radar altimeter.
  - Precise Range and Range-rate Equipment PRARE.
  - Laser Retroreflector.
- Earthnet: ESA's remote sensing satellite ground segment, at present comprising 5 ground stations located in Europe, Canada, Canary Islands. Acquisition, processing and archiving of data from remote-sensing satellites and (later) ERS and Polar Platforms.
- Meteosat Operational Program, a series of three geo-stationary meteorological satellites to be procured and operated for EUMETSAT.

Implementation Period 1989 to 1993

- Earth Observation Preparatory Program EOPP
  - multi-disciplinary study program to advanced program conception and definition to system feasibility (Phase A) level.
  - limited technology research for advanced instrumentation.

- Solid Earth Program in preparation is ARISTOTELES to be launched in 1995 with primary (gravity field) and optional (magnetic field, geodetic point positioning) mission objectives.  
Orbits: 200 km (6 months) and 700 km (few years)  
Payloads under consideration: gradiometer, magnetometer, GPS receiver, precise tracking system  
Data analysis studies: simulate gradient sensor derivation; simulation of regional gravity potential recovery.

#### **Current International Activities:**

ESA plays an active role in many international groups and committees concerned with the coordination of existing and future Earth observation missions:

IPOMS	IFEOS
CGMS	ICWG
CEOS	

Typical examples of current cooperation:

- Use of data - ERS-1 Announcement of Opportunity (1986)
- Tracking support - ERS-1 worldwide laser tracking
- Acquisition support - ERS-1 SAR data reception by NASA station in Fairbanks
- Joint development - Space Telescope

#### **Elements of ESA/NASA Cooperation:**

ESA-NASA Solid Earth Plans:

- |          |  |
|----------|--|
| 1985:    | AGU Spring Meeting<br>GRM Steering Committee discussed opportunities of combining GRM (USA) and POPSAT (ESA) |
| 1986:    | SESAME WORKSHOP recommends the pursuit of European Solid Earth program with USA                              |
| 1986/87: | Joint ESA/NASA study team examines options   |
| 1987:    | MATERA WORKSHOP - consensus about single-spacecraft geopotential mission                                     |

- 1987/89: ESA continues with feasibility study (Phase A) for ARISTOTELES
- July 89: Coolfont report of NASA Program Panel indicates that NASA now sees concrete ways for cooperation between the two Agencies.

